Effect of Polymer Film Permeability on Retarding or Preventing Corrosion

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Background:
Impact and Causes of corrosion

- Economic impact of rust:
  - total corrosion worldwide costs between 1% and 5% of a nation's GDP*
- Moisture in the surrounding environment enables rust formation
- Rust (corrosion) results from electrochemical reactions at high humidity conditions where a thin film of water can form on the surface of metals

Koch, G. H., Brongers, M. P. H., Thompson, N. G., Virmani, Y. P., and Payer, J. H., Corrosion Costs and Preventive Strategies in the United States. FHWA-RD-01-156. 2001. Springfield, VA, National Technical Information Service.

Background: significance of moisture vapor control

If products are wrapped, covered, or packaged in a plastic bag (or film) during shipment or storage

…and the plastic film has a low water permeability…

some condensed water may be trapped inside because there is no way for water to escape

This condensed water would be highly likely to initiate and accelerate corrosion

If instead…

the plastic film has high moisture permeability…

corrosion may be reduced because condensed water can quickly escape

So..

packaging in a plastic film with higher moisture permeability may prevent corrosion

What polymer chemistries can accomplish this?

Vapor Permeability Data: commercial resins

	O_2, cc-mil/m^2day	H_2O, g-mil/m^2day
HDPE	1560- 3000	4 – 6.4
LDPE	2600-7600	12 – 24
mPE	2000-21600	4 - 8
Styrene-butadiene	6400 - 10400	44 -56
PP	1400-4560	16 – 48
Nylon 6	12 - 80	60 – 360
EVOH, 32/44 mole%	0.4/1.2	32/96
OPET	48 – 96	16 – 32
Polyether amide	8000 - 36000	12000 - 40000
Polyether ester	48000 – 56000	8000 - 36000

Gaps in the range of available WVTR

** Measured at 20 – 25 C; data from **Permeability Properties of Plastics and Elastomers,** L.K. Massey*

Permeability of Commercial Resins

- Few commercially available resins with WVTR between conventional olefin copolymers (<60 g-25um/m^2day) and the very permeable polyether amides and polyether esters (8000–40000 g-25um/m^2day)
  - Few options make finding a balance of permeability and physical properties difficult
- Coextrusion of the very breathable materials with conventional resin as a way to tailor WVTR is problematic
  - permeability of a coextruded film is a weighted average of the components - coextrusion with even a very thin layer of a lower WVTR material will greatly reduce the WVTR of the coextruded structure
- Blending to increase WVTR is also problematic:
  - limited compatibility between the polyetheramides or polyetheresters with the moderate WVTR polymers
  - difficult to produce blends with balanced mechanical and optical properties

DUPONT®

Novel Resin Technology

Based on modified ionomer chemistry

- Physical properties comparable to conventional ionomers
  - blending with other ethylene copolymers
- WVTR can be tailored
  - 3000 – 15000 g-25um/m2day

Testing Procedure: Corrosion Resulting from Trapped Water

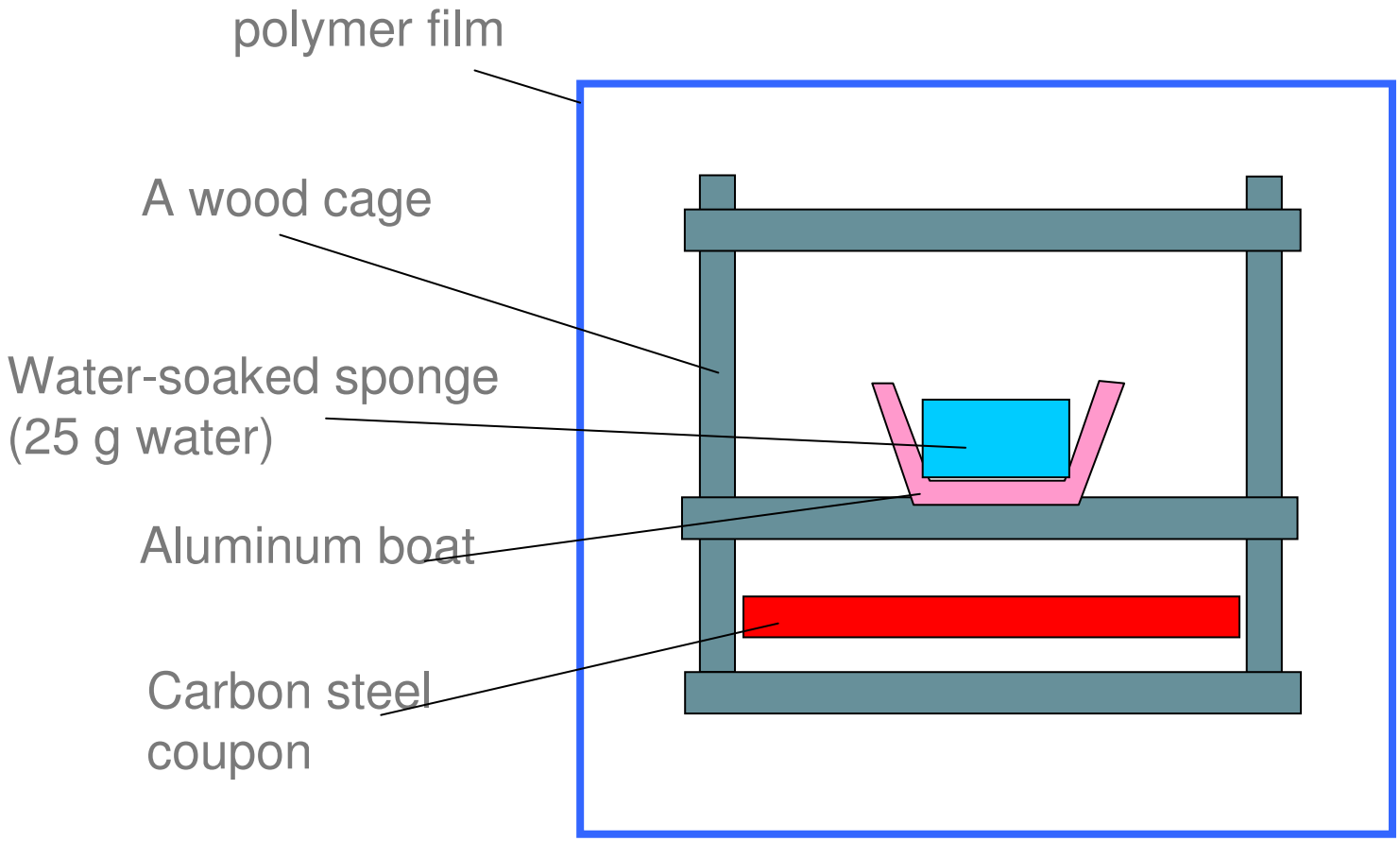
Films tested 60C/50% RH

- Evaluate effect of water inside the package
  - test apparatus keeps carbon steel coupons exposed to water vapor (100% relative humidity) but separated from liquid water
  - apparatus placed inside a bag of the test film (fabricated by heat sealing)
  - apparatus is placed in an environmental chamber to control the external temperature and humidity
- Evaluate effect of water ingress through a permeable package
  - Pack coupons in bags at 23C/50% RH, store at 60C/85% RH

Photographs taken of the coupons after testing

amount of surface area covered by rust quantified via Adobe Photoshop

Trapped Water Corrosion Test: Experimental set up Schematic



The experimental set up:
support frame inside a plastic bag

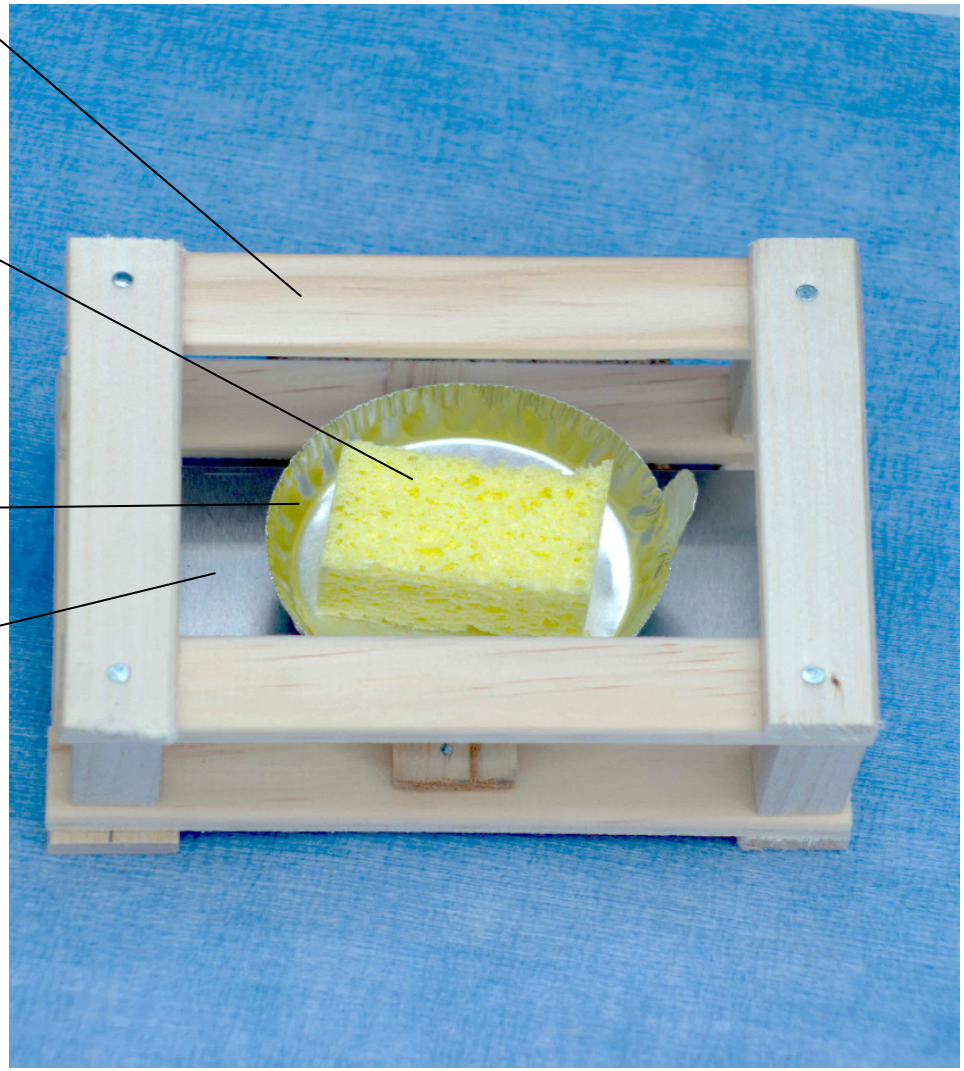
Corrosion Test: Experimental set up

wood cage

Water-soaked sponge

Aluminum boat

Carbon steel coupon



Experimental: test films

Resin	WVTR, g-25um/m2day
PE (control):	20
Med. Perm film	1300
High perm film	4300

All tested at 2 mil thickness

Results: Corrosion test

- Trapped water inside package
- Ambient storage conditions

Trapped water: Results at 60C/50% RH

PE Control

Med. Perm film

High Perm. film

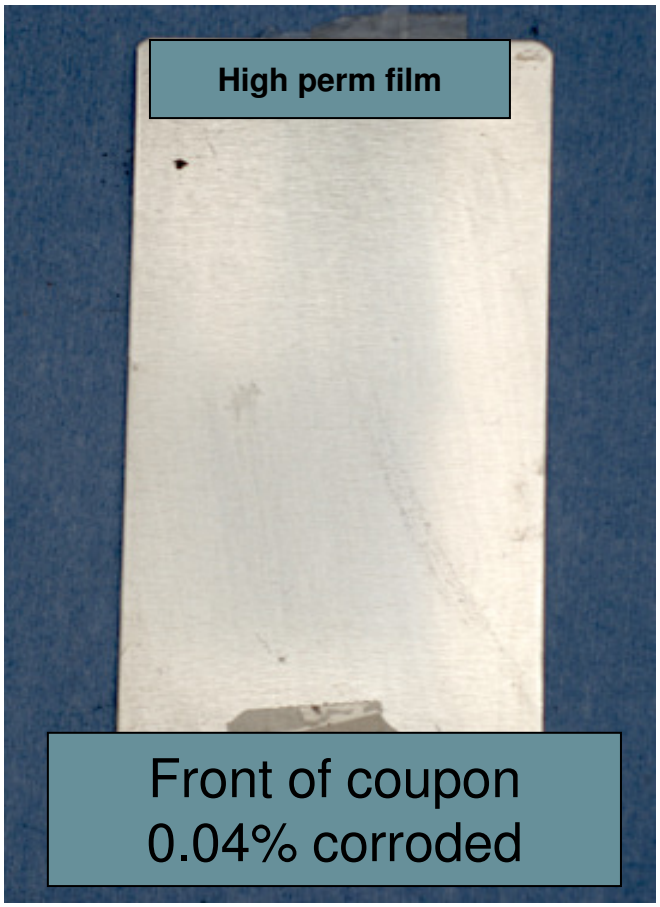
The apparatus after the test
Note absence of fogging with high perm. film

Quantification of corroded areas using Adobe Photoshop 7

Test Coupons after exposure

Test Coupons after exposure

Test coupons after exposure



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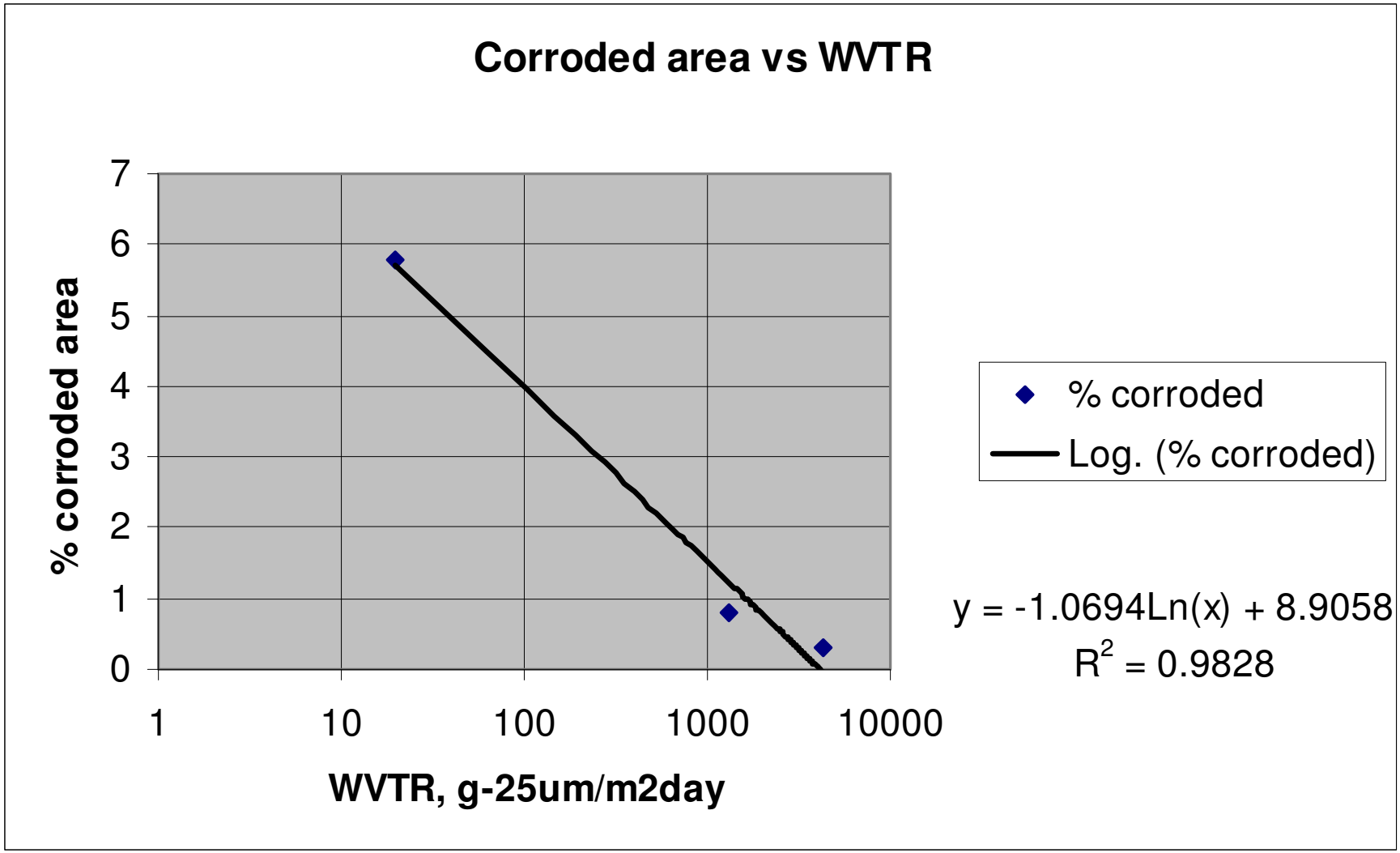
Summary:
Corroded area versus the permeation rate of films

Film ID	Permeation rate (g-25u/m2day)	Corroded area			
		Sample	Front side	Back side	Average
PE	20	1	2.2 %	3.5 %	5.8 %
		2	13.8 %	3.7 %	
Med. Perm film	1300	1	0.61 %	0.56%	0.74%
		2	0.03 %	1.75 %	
High perm film	4300	1	0.34 %	0.74 %	0.3%
		2	0.04 %	0.08 %	

Results: Effect of WVTR on Corrosion



No corrosion if WVTR is greater than 1360 g/m2day

Discussion: trapped water corrosion testing

- Under conditions of trapped high humidity, a more permeable film provides better corrosion protection than a less permeable film
- The severity of corrosion is inversely proportional to film's water permeation rate

Conclusion

•The concept that a high permeation film could be efficacious in reducing corrosion due is confirmed

•Magnitude of the effect depends on permeability of film, temperature, and relative humidity of environment

Novel high WVTR resins based on ethylene copolymers fill in the spectrum of available WVTR and enable new options for protecting covered articles from corrosion

Permeability Data: commercial and developmental resins

	O_2, cc-mil/m^2day	H_2O, g-mil/m^2day
HDPE	1560- 3000	4 – 6.4
LDPE	2600-7600	12 – 24
mPE	2000-21600	4 - 8
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OPET	48 – 96	16 – 32
Polyether amide	8000 - 36000	12000 - 40000
Polyether ester	48000 – 56000	8000 - 36000
developmental ionomers	2000 - 5800	3000 - 13000

Thank you!